Glass and Ceramics, Vol. 70, Nos. 5 – 6, September, 2013 (Russian Original, Nos. 5 – 6, May – June, 2013)

UDC 666.1

STRENGTH EFFECT OF DIFFERENT TREATMENT METHODS FOR SILICATE GLASSES

M. E. Kustov,[1, 2] I. S. Kurchatov,[1] É. N. Murav'ev,[1] V. I. Revenko,[1] V. F. Solinov,[1] and E. F. Solinov[1]

Translated from *Steklo i Keramika*, No. 5, pp. 22 – 24, May, 2013.

Statistical data obtained on the mechanical strength of the glass from tests performed on glass samples treated by different methods are examined. It is shown that the deposition of a metalized film on glass decreases glass strength and virtually no further strength degradation occurs when the film is removed by means of laser radiation.

Key words: glass, treatment methods, strength, coatings.

A decrease of the surface (interphase) energy due to physical or chemical processes on the surface of solids changes the mechanical properties: strength and durability loss, brittleness onset, plasticity increase and other changes. Strength loss due to adsorption, known as the Rebinder effect [1], occurs with the adsorption of surfactants, wetting of solids by melts with similar atomic-molecular character, electrostatic charge formation on the surface due to chemical reactions and external electric fields and film deposition and formation on a glass surface. To study these phenomena a series of experiments investigating the mechanical strength of the glass used for articles used in structured optics (ASO) with different types and technologies of surface treatment of glass was conducted. Special attention was devoted to the effect of laser cutting and working of a glass surface in order to validate the prospects for using this technology in the production of ASO.

For this investigation $60 \times 60 \times 3$ mm glass samples were prepared in order to measure the centrosymmetric bending (CSB) strength (MPa) and $120 \times 18 \times 6$ mm samples for measuring three-point bending strength with different types of treatment of the glass surface.

Glasses with the following main methods of surface treatment were used in this work:

1) ion exchange (IE);

2) ion exchange followed by deposition of an In_2O_3 film (the film working in compression or tension, i.e., it lay on the inner or outer surface of bending, respectively);

3) ion exchange followed by deposition of an In_2O_3 film and creation of a resistive circuit with the aid of insulating cut-offs (the film worked in compression or tension).

The results of the investigation are presented in Table 1 and Fig. 1.

An In_2O_3 film on a glass surface decreases the bending strength of the glass sample; when the film is in compression

TABLE 1. Centrosymmetric Bending Strength of Sample with Different Types of Treatment

Sample	Treatment types	σ_a, MPa
1	Thermally polished sheet glass	122
2	Quartz glass	136*
3	Vertically drawn sheet glass	30**
4	Quartz glass with defects	41**
5	Glass with ion exchange (IE)	446
6	Glass with ion exchange and In_2O_3 film (tension***)	343
7	Glass with ion exchange and In_2O_3 film (compression***)	417
8	Glass with In_2O_3 film (compression***) with cut-offs made by chemical technology (CT)	386
9	Glass with ion exchange (45°C) and an In_2O_3 film (tension***) with cut-offs made by laser technology (50-watt LT)	391

* Data of [2].

** Data of [3].

*** Film working with the sample in bending.

[1] Scientific-Research Institute of Technical Glass, JSC, Moscow, Russia.
[2] E-mail: gigaset2009@gmail.com.

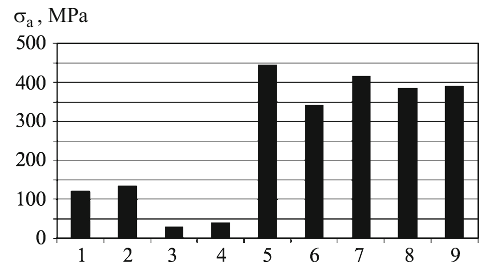

Fig. 1. Centrosymmetric bending strength σ_a of glass blanks with different surface treatment (see Table 1, Nos. 1 – 9).

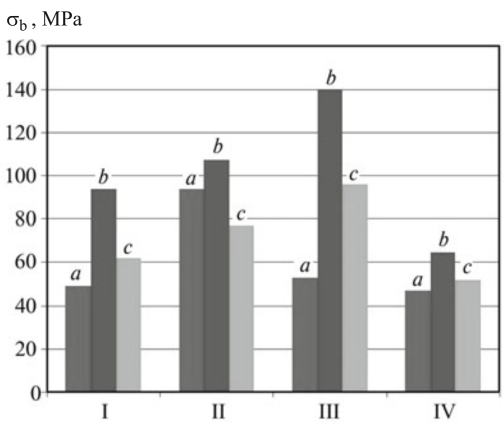

Fig. 2. Transverse three-point bending strength σ_b of glass blanks with different types of cutting: laser (see Table 2, sample 3) and mechanical (see Table 2, sample 4): I) thermally polished sheet glass; II) quartz glass; III) sheet glass in tension cut with a laser; IV) sheet glass in tension cut with a glass cutter [*a*) min, *b*) max, *c*) average values].

this change is small but for the stress acting in the opposite direction, when the film is in tension, the bending strength of the glass samples decreases by almost 20% (Fig. 2).

This shows that the adhesion of the film to the glass surface is strong. When the film is in tension the surface layers beneath the glass film stretch and create addition tensile stresses in the glass. When the film is in compression the surface layers of the glass beneath the film are compressed and

TABLE 2. Transverse Three-Point Bending (TPB) Strength σ_b with Different Types of Glass Treatment

Sample	Treatment types	σ_b, MPa		
		min	max	average
1	Thermally polished sheet glass*	49	94	62
2	Quartz glass*	94	107	77
3	Sheet glass, in tension, laser cutting	53	140	96
4	Sheet glass, in tension, cutting by glass cutter	47	65	52

* Data from [2].

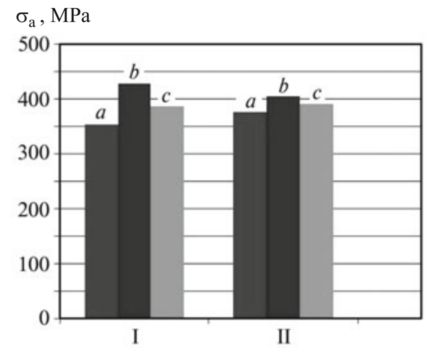

Fig. 3. CSB strength σ_a of glass blanks with cut-offs created by laser and chemical technologies and with different treatments: with cut-offs by laser (see Table 1, sample 9) and chemical (Table 1, sample 8) technologies with centrosymmetric bending: I) glass with film with CT cut-offs; II) ion-exchange glass (45 °C) with film and LT cut-offs [*a*) min, *b*) max, *c*) average values].

create additional compression stresses in the glass. Since the strength of the glass in tension is lower than in compression, a significant difference in its values arises depending on the direction of bending relative to the film.

Glass hardened by ion exchange shows the highest CSB strength (see Table 1, sample 5) — 446 MPa. Glass hardened by ion exchange with an In_2O_3 film acting in compression with no cut-offs exhibits somewhat lower strength (Table 1, sample 7) — 417 MPa. Glass with an In_2O_3 film in compression with cut-offs has lower strength — 386 MPa with cut-offs created by chemical technology (see Table 1, sample 8) and 391 MPa with cut-offs created by the LT method (see Table 1, sample 9). Hence it can be concluded that the strength of glass with LT cut-offs is no lower than with chemically deposited cut-offs. The strength of thermally polished sheet glass is 122 MPa (see Table 1, sample 1), a factor of 3 lower, and of quartz glass136 MPa (see Table 1, sample 2). The presence of defects in the interior and on the surface of glass is significant; the strength of the glass is almost an order of magnitude lower — 30 MPa (see Table 1, sample 3) and 41 MPa (see Table 1, sample 4).

We shall now compare the effect of the glass cutting method on the strength of the glass. The strength of glass articles in this case was measured by transverse three-point bending (TRB). The results are presented in Table 2 and Fig. 2.

The transverse three-point bending strength of glass blanks with laser cutting in tension (see Table 2, sample 3) is almost a factor of 2 greater — 96 MPa than with mechanical cutting with a glass cutter (see Table 2, sample 4) — 52 MPa (see Fig. 2) and greater than that of sheet and quartz glass (see Table 2, samples 1 and 2).

Data on the CSB strength of glass with different methods of creating cut-offs — laser (see Table 1, sample 9) and chemical (see Table 1, sample 8) technologies — are compared in Fig. 3. It can be concluded on this basis that the two technologies give practically the same strength of articles.

The results obtained in this work make it possible to evaluate the effect of different types of surface treatment of glass — ion exchange, deposition of current-conducting coatings, formatting of films on the surface by laser and chemical technologies as well as by mechanical and laser cutting of glass — on the strength characteristics and relative durability of the glass when working with prescribed mechanical and thermoelastic stresses.

It was shown that for all practical purposed the laser technology used to format films on a glass surface does not decrease the strength of glass articles.

REFERENCES

1. P. A. Rebinder, *Selected Works on Physical-Chemical Mechanics: Surface Phenomena in Disperse Systems* [in Russian], Moscow (1979).
2. V. A. Brest and V. I. Shelyubskii, “Strength of glass under long-time loading,” *Steklo Keram.*, No. 6, 14 – 16 [1991]; V. A. Brest and V. I. Shelyubskii, “Strength of glass under a prolonged load,” *Glass Ceram*., **48**(6), 247 – 250 [1971].
3. V. I. Shelyubskii and N. A. Velikovskaya, “On picking a value for the ultimate strength of the glass for glass articles,” *Steklo Keram.*, No. 5, 4 – 8 (1971); V. I. Shelyubskii and N. A. Velikovskaya, “The choice of the value for the ultimate strength of the glass in the design of glass articles,” *Glass Ceram*., **28**(5), 273 – 278 (1971).